

**Codes and Standards Enhancement Initiative
For PY2004: Title 20 Standards Development**

**Analysis of Standards Options
For
Open Case Refrigerators and Freezers**

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1 Introduction

The Pacific Gas and Electric Company (PG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC) and other stakeholders in the development of these new and updated standards. The objective of this project is to develop CASE Reports that provide comprehensive technical, economic, market, and infrastructure information on each of the potential appliance standards. This CASE report covers standards and options for open case refrigerators and freezers.

2 Product Description

Open Case Refrigerators and Freezers (hereafter referred to as Open Case(s)) refer to medium temperature (the temperature range for refrigeration applications maintaining contents, e.g. dairy products, above freezing) and low temperature (the temperature range for refrigeration applications maintaining contents in a frozen state) refrigerated cases, without doors, that allow free access to contents, generally food and beverage products. Open Cases come in several different configurations, such as multi-deck, single level, and crowned (center is raised relative to the edges).

Open Cases are normally constructed with a painted, galvanized sheet metal exterior and with internal components, including the refrigeration system components, lighting, insulation, and shelves where appropriate. They have the basic components of a refrigeration system: evaporator, condenser (with fan) and compressor. The evaporator is inside the Case and consists of a heat exchanger and fans. The rest of the refrigeration system (the condenser and compressor) comes in one of three configurations: 1) compressor and condenser integrated in the Case, 2) compressor integrated in the Case and the condenser remotely located, and 3) compressor and condenser remotely located. The compressor and condenser in each of these scenarios can either supply refrigeration to that Open Case only or to other equipment, but the compressor and condenser in configuration one and two usually supply only that Case or a group of joined Open Cases.

Open Cases are normally found in supermarkets and convenience stores. The products displayed in these Open Cases include meat, frozen foods, beverages, dairy products, and produce. The main selling feature of these Open Cases is their effectiveness at merchandizing goods; allowing customers to easily see and retrieve the goods displayed. The product is cooled by a blanket of refrigerated air that circulates in the Case from top to bottom or side to side depending on the style of Case. Normally Open Cases come in standard sizes from four to twelve feet long and some can be joined together to create Open Cases of seventy-two feet and longer.

Single level Open Cases have one level and no shelves (Figure 1). They are sometimes crowned for better product merchandizing. Multi-deck Open Cases have one or more shelves (decks) that rise vertically from the main platform (Figure 2). Products are easily viewed and retrieved in this configuration.

Figure 1 Typical Single Level Case



Figure 2 Typical Multi-Deck Case



Five manufacturers produce the vast majority of Open Cases sold nationally. The larger manufacturers of Open Cases are Hussmann, Kysor Warren, Hill Phoenix, Tyler, and Zero Zone. Large supermarket and convenience store chains are key stakeholders on the purchasing side.

3 Market Status

3.1 Market Penetration

California-wide penetration data is interpolated from the ADL report, which provided only national statistics, by multiplying the national data by the ratio of California population to the national population. According to U.S. Census estimates, California has about 12% of the nation's population. Thus, it is assumed that California would have approximately 12% of the nation's supermarkets. There are 32,265 supermarkets in the United States, which, therefore, translates to 3,904 supermarkets in California (FMI 2002d). The average supermarket will have from 60 to 80 display cases. Of these over half or almost 45.6 are believed to be Open Cases) (ADL 1996). Based on the estimated number of supermarkets, stock of California Open Cases in supermarkets is estimated to be 178,000. Because the penetration of Open Cases in non-supermarket groceries and convenience store is unknown, but presumed to be substantially less than in supermarkets, we do not include this non-supermarket segment in this estimate.

3.2 Existing and Future Sales

The life of Open Cases is approximately 10 years depending on maintenance and environment, though some have been in service many years beyond this. Based on an assumed life of 10 years and 178,000 units in service, we estimate annual sales of 17,800 units in California (ADL 1996). Given the trends for sales of frozen and prepared foods, and the general growth of California, it is likely that sales will continue to increase for the foreseeable future.

3.3 Market Penetration of High Efficiency Options

The supermarket Open Cases market is first-cost sensitive (FMI 2002a). Interestingly, however, average grocery store after tax profit is 1.25% of sales--roughly equal to the utility costs (FMI 2002b, FMI 2002c). Despite the apparent significance of typical energy savings, purchasing agents look for display cases from primarily a merchandizing angle and are more focused on sales than energy costs.

Some manufacturers have Open Cases that they advertise as “energy efficient”. Most manufacturers include energy efficient lighting in current products. Many also provide efficient fan options, as well. With the exception of efficient lighting,¹ which may be installed in over ninety percent of recent Open Case sales, and given the lack of data available on energy use and efficiency, it is likely that the penetration of efficiency options is low. Thus, we conclude that the remaining savings opportunity is large.

4 Savings Potential

4.1 Baseline Energy Use

Baseline energy use data is very sparse. Limited test data show that older, medium temperature upright multideck meat Open Cases use approximately 1750 Btuh per lineal foot of Case display and that one newer Case tested used approximately 1200 Btuh/ft at 75 degree dry bulb and 55% relative humidity (Faramarzi & Kemp1999c)². Data from the *Energy Savings Potential Report for Commercial Refrigeration Equipment*, (ADL 1996) shows multideck medium temperature Open Cases use 1500 Btuh/ft. The average of the test data loads for the new and old multideck Open Cases above $((1750 + 1200) \text{ Btuh/ft} / 2 = 1475 \text{ Btuh/ft})$, is close to that reported by ADL (1500 Btuh/ft). Additionally, the ADL report shows refrigeration loads of 550 Btuh/ft for single level low temperature Open Cases. Single level Open Cases have less refrigeration load than multideck Open Cases because the air curtain is horizontal rather than vertical, and there is less ambient air infiltration, which greatly reduces refrigeration loading. Most low temperature Open Cases are single level. Most multideck low temperature cases have doors because of the high refrigeration loads associated with low temperature air curtains. Therefore, in the analysis of low temperature Open Cases, we focus on single level cases.

As noted in section 3.1 above, California saturation data is interpolated from the ADL report. Supermarkets (grocery stores with over \$2,000,000 in annual sales) account for 77% of the total grocery store sales, which would indicate the supermarkets account for at least 77% of the energy costs for all grocery stores, since sales are closely related to utility costs in grocery stores (FMI 2002a, FMI 2002d). There are 32,265 supermarkets in the United States, which translates to 3,904 supermarkets in California (FMI 2002d). The ADL report assumed a typical supermarket area of 45,000 sq. ft., which is approximately equal to the average size supermarket (44,000 sq. ft.) (FMI 2002d). Because the penetration of Open Cases in non-supermarket grocery and convenience stores is unknown, but presumed to be substantially less than in supermarkets, we conservatively base this analysis only on Open Cases in supermarkets representing perhaps 80 to 90

¹ Based on conversations with several manufacturers representatives.

² While performance data reported in this report was often reported in Btuh per lineal foot, we propose that analysis of performance be assessed in terms of cubic feet.

percent of Open Cases in the State. This may understate state-wide impacts by 10 to 15 percent. Based on the estimated stock of 178,000 Open Cases in supermarkets throughout California, the annual statewide energy consumption is estimated at 2,700 GWh and 416 MW.

4.2 Proposed Test Method

The most appropriate standard testing procedure for measuring the relative energy efficiency of open case refrigerators and freezers is *ASHRAE Standard 72-1998 Method of Testing Open Refrigerators*. This test procedure is currently being revised and combined with Standard 117-2002 (for closed refrigerators). The composite standard, which is now in draft form, is called BSR/ASHRAE Standard 72-1998R (Method of Testing Open and Closed Commercial Refrigerators and Freezer). The standard is now in for the second round of public comment and will probably be adopted sometime in 2004. The Standard details the purpose, test conditions, instrumentation, test procedures, measurement locations, apparatus, presentation, energy calculations, and reporting of test results for open and closed case refrigerators and freezers (ASHRAE 1998).

Until 72-1998R is finalized and referenced by the Commission in a future proceeding, ASHRAE Standard 72-1998 test procedures will yield energy usage in kWh per day. "Load line volume" as defined in ASHRAE Standard 72-1998 can be then used to calculate normalized energy use or kWh per cubic foot per day, which would be an appropriate performance metric for a future, prescriptive standard. Again, under such a test procedure performance would be expressed in terms of energy per cubic foot rather than per lineal foot, the metric used in the ADL report.

4.3 Efficiency Measures

Some manufacturers have Open Cases that they advertise as "energy efficient" and most manufacturers have optional energy efficient light and fans available now. Some manufacturers offer energy efficient components as options and other as standard equipment. Below is a list of efficiency measures or strategies that currently are or could be integrated into Case design:

- 1) Night covers for display cases*
- 2) Suction line insulation* (for remote systems)
- 3) Evaporator fan controller*
- 4) Oversized condenser (self-contained units)
- 5) Water-cooled condenser (probably not practical with self-contained units)
- 6) Increased evaporator surface area or efficiency to lower case/evaporator temperature differential (possible increase in fan energy)
- 7) Air curtain design changes.
- 8) Remote lighting ballast location (outside of refrigerated space)
- 9) Hot gas defrost
- 10) Anti-condensate heat control

- 11) Evaporator* and Condenser fan electronically commutated motor (ECM) or permanent split capacitor (PSC) motor
 - 12) Defrost control (for hot gas or electric defrost)
 - 13) High efficiency lighting*
 - 14) Liquid suction heat exchanger: subcool liquid refrigerant with suction line
 - 15) Increased envelope insulation
 - 16) High efficiency fan blades
- * California IOUs offer incentives for performance based efficiency retrofits, including, but not limited to these measures.

4.4 Standards Options

Up to 75 percent of the refrigeration load in Open Cases is caused by ambient air infiltration into the Case (Faramarzi & Kemp1999a). Addressing this large savings opportunity will likely require substantive re-engineering of Open Cases. Generally, where such significant change is desired, performance-based standards are more likely to provide maximum freedom for manufacturers to innovate and optimize design solutions with respect to costs and customer utility attributes. Despite the large savings potential, the dearth of measured performance data recommends against setting a performance standard at this time.

In the short run, a prescriptive Case lighting and evaporator fan motor standard should be implemented while performance baseline data are developed in support of future performance-based standards needed to pursue the larger savings opportunities. A prescriptive lighting standard is now feasible because most major manufacturers are already installing high efficient lighting in the vast majority of their Open Cases (perhaps 95 percent or more) (Hussmann, 2003, Kysor, 2003, Hill Phoenix, 2003). The materials (T8/T5 lamps and low temperature electronic ballasts) are readily available. Even though most new Open Cases made by the major manufacturers have energy efficient lighting, a standard will ensure that all Open Cases from small and large manufacturers have energy efficient lighting.

4.5 Energy Savings

Data for energy savings for measures 9 through 16 above are listed in Table 1. The data indicates that there is a tremendous opportunity for energy savings. Application of the measures described in Table 1 would together result in 567GWh and 58.3 MW savings if all Open Cases were replaced at once. These numbers should be adjusted downward because most major manufacturers are now installing energy efficient lighting. The adjusted numbers would be 522GWh and 53.3 MW savings. As previously noted, these savings numbers are for supermarkets only, which make up approximately 80 to 90 percent of the total potential savings.

Using current penetration of efficient lighting, the remaining lighting savings potential is approximately five percent of that shown in Table 1 below, or about two Gigawatt-hours. The requirement of an ECM motor for evaporator fans would provide an additional 158 GWh and 21 MW peak reduction. First year savings are estimated to be approximately 16 GWh and 2 MW peak load reduction.

Table 1: Supermarket Case Energy Savings for California

Typical Supermarket Baseline Electric Usage 1,572,000 kWh Demand 242kW	Energy Reduction (kWh/yr)	Load Reduction (kW)	Incremental Cost** (\$)	Annual Energy Savings*** (\$)	Simple Payback (years)	Total CA Load Reduction (MW)	Total Annual Energy Savings for (GWh)
Hot Gas Defrost	11,597	0	\$ 1,058	\$ 688	1.5	0	45
Antisweat Heat Control	16,600	0	\$ 1,637	\$ 985	1.7	0	65
Evaporator Fan ECM Motor~	40,494	4.6	\$ 4,709	\$ 3,118	1.5	18.0	158
Defrost Control (Hot Gas) 31%	2,598	0	\$ 1,196	\$ 154	7.8	0	10
Defrost Control (Electric) 69%	6,923	0	\$ 1,300	\$ 411	3.2	0	27
High Efficiency Lighting	11,405	1.3	\$ 1,638	\$ 876	1.9	5.0	45
LSHX* Low Temp.	16,248	3.0	\$ 5,096	\$ 1,422	3.6	11.5	63
LSHX* Med. Temp.	21,584	3.9	\$ 22,585	\$ 1,881	12.0	15.1	84
Insulation Improvements	2,016	0.4	\$ 5,016	\$ 177	28.4	1.4	8
High-Efficiency Fan Blades	15,842	1.8	\$ 54	\$ 1,222	0.04	7.1	62
Annual Savings Potential	145,308	14.9	\$ 44,289	\$ 10,934	4.1	58.3	567
Measures with 4>Payback	119,110	10.7	\$ 15,491	\$ 8,722	1.8	41.7	465

Based on ADL, 1996 data, scaled where necessary for California

~ ECM = Electronically Commutated Motor

*LSHX = Liquid Suction Heat Exchangers

**Escalated from ADL data by 18.9% assuming 2.5% inflation rate

***Using PG&E E-19 rate schedule assuming constant loading and no adders

5 Economic Analysis

5.1 Incremental Cost

Incremental cost data is provided in the Table 1, "Incremental Cost" column. This data shows that for new equipment the majority of efficiency measures have under a 4 year payback, and all those measures with less than a four year payback combined have an average payback of less than 2 years. For the typical supermarket, the savings are 7.5 percent of the refrigeration cost at a cost premium of about \$15,000 for a 100 ton system. This incremental cost is less than two percent of the cost of such a system (ADL, 1996). For efficient lighting alone, the incremental cost of efficient lighting was reported to be \$1,638 per average supermarket (ADL, 1996) or about \$40 per Open Case (assuming 45.6 Open Cases per supermarket). This measure has a demand reduction of approximately 29 watts and therefore a simple payback of less than two years.

5.2 Design Life

The Pacific Gas and Electric Company efficiency program filings indicate a design life for most individual refrigeration components of 11 to 16 years (PG&E, 2002). To be

conservative for the purposes of the present value assessment, the design life used in this analysis is 10 years.

5.3 Life Cycle Cost

Life cycle costs for the measures in Table 1 are presented below in Table 2. The present values of savings were calculated using a Life Cycle Cost of \$0.709 annual kWh savings for 10-year measures (CEC 2001). The customer's Net Present Value is positive when the life cycle cost of ownership is reduced by the measure.

Table 2: Analysis of Customer Net Benefit

Standard Option	Design Life (years)	Annual Energy Savings kWh	Present Value of Saved Energy**	Incremental Cost (\$)	Net Customer Present Value***
Hot Gas Defrost	10	11,597	\$ 8,223	\$ 1,058	\$ 7,164
Antisweat Heat Control	10	16,600	\$ 11,769	\$ 1,637	\$ 10,132
Evaporator Fan ECM Motor~	10	40,494	\$ 28,710	\$ 4,709	\$ 24,001
Defrost Control (Hot Gas) 31%	10	2,598	\$ 1,842	\$ 1,196	\$ 646
Defrost Control (Electric) 69%	10	6,923	\$ 4,908	\$ 1,300	\$ 3,609
High Efficiency Lighting	10	11,405	\$ 8,086	\$ 1,638	\$ 6,448
LSHX* Low Temp.	10	16,248	\$ 11,520	\$ 5,096	\$ 6,424
LSHX* Med. Temp.	10	21,584	\$ 15,303	\$ 22,585	\$ (7,282)
Insulation Improvements	10	2,016	\$ 1,429	\$ 5,016	\$ (3,587)
High-Efficiency Fan Blades	10	15,842	\$ 11,232	\$ 54	\$ 11,178
Annual Savings Potential	10	145,308	\$ 103,023	\$ 44,289	\$ 58,735
Measures with 4>Payback	10	119,110	\$ 84,449	\$ 15,491	\$ 68,958

Based on ADL, 1996 data, scaled where necessary for California

~ ECM = Electronically Commutated Motor

*LSHX = Liquid Suction Heat Exchangers

** Present value of energy savings calculated using a life cycle cost of \$0.709 per annual kWh saved.

*** Positive value indicates a reduced total cost of ownership over the life of the appliance.

As noted above, the remaining statewide savings potential from efficient lighting requirement alone is small at 2 GWh per year (since 95 percent or more of Open Cases appear to be shipped with better lighting). Though relatively small on a statewide basis, these savings would be quite cost effective on a life cycle basis with the net present value of \$141 per Open Case at approximately four times the incremental cost of \$36 per Open Case as shown above (on a supermarket basis).

6 Acceptance

6.1 Infrastructure Issues

Some manufacturers offer energy efficient components as options and others as standard equipment, but there appears to be little available, comprehensive energy efficiency test data to enable direct comparison of products. Preliminary conversations with some manufacturers (Kysor, 2002, Artic Air, 2002) show interest in providing energy efficient

Open Cases to the California market. On the other hand, large retailers always have concerns about product safety, cost and merchandizing efficacy (i.e., sales).

Some manufacturers already have Open Cases that they advertise as “energy efficient”. Preliminary assessments indicate that product redesign could be a lengthy process for some products (depending of the rigor of a proposed performance standard). A more detailed assessment of the infrastructure issues relating to the development of overall performance standards would be required to determine whether simple modifications or more comprehensive redesign would be required of most manufacturers to comply with a robust performance standard. Most manufacturers, however, ship Open Cases with energy efficient lighting now. Higher efficiency motors are commonly available and cost effective. Thus, establishing lighting efficacy and evaporator fan motor standard in the current proceeding is not expected to be problematic for stakeholders.

6.2 Existing Standards

There are no existing comprehensive standards at this time. Canada is working on a standard titled: “C657-03 Energy Performance Standard for Refrigerated Display Cabinets (Merchandisers); February 15, 2003 Draft” that may serve as a model for creation of a future California Case performance standard.

Illumination standards for many similar refrigerated appliances are included in 1605.3.a.3 of Title 20 Appliance Efficiency Regulations.

7 Standards Recommendation

Due to the large savings opportunities from Open Cases, a performance standard appears desirable. Given the lack of available, comprehensive performance data at this time, however, development of an appropriate performance standard as part of this Title 20 proceeding would be difficult. While performance standards are not feasible in the current proceeding, we recommend that the Commission require testing and listing of Open Cases starting in January 1, 2006 in order to proceed with collection of performance data to facilitate future consideration of Open Case performance standard. Furthermore, we note that different Open Case configurations may require different standards levels due to the inherent difference in energy use characteristics (e.g., multi-deck versus single level, and low temperature versus high temperature).

Prescriptive lighting efficacy and ECM evaporator fan motor (or equivalent) standards are recommended for this proceeding. Most major manufacturers are already offering high efficiency lighting with their Open Cases, and the materials (T8/T5 lamps and low temperature electronic ballasts) are available in the quantities that would be required. Even though most new Open Cases made by the major manufacturers have energy efficient lighting, a standard is needed to insure that all Open Cases from small and large manufacturers have energy efficient lighting. The additional requirement of an ECM motor is clearly cost effective and

A simple prescriptive lighting standard should amend existing Title 20 1605.3.a.3 to read:

*“(3) **Energy Design Standard.** Internal illumination of the following appliances, manufactured on or after March 1, 2003,(except Open Case Cabinets which should take effect on or after January 1, 2006) shall be only by (1) T-8 fluorescent lamps*

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with electronic ballasts, or (2) a lighting system that has no fewer lumens per watt than a system using only T-8 fluorescent lamps with electronic ballasts.

(A) refrigerating bottled or canned beverage vending machines;

(B) reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets, with transparent doors;

(C) wine chillers that are not consumer products; and

(D) open case cabinets.”

Additionally, a new design standard requiring that evaporator fan motors in Open Cases are required to have ECM type or equivalent efficiency fan motors.

Furthermore, Table U in section 1606 should have a section added for manufacturer reporting purposes.

<i>Open Case Refrigerators and Freezers</i>	<i>*Cabinet Style</i>	<i>Packaged, .</i>
	<i>*Defrost System</i>	<i>Automatic, manual, partial-automatic</i>
	<i>*Type</i>	<i>Refrigerator, refrigerator-freezer, freezer</i>
	<i>*Door Style</i>	<i>Solid hinged, solid sliding, transparent hinged, transparent sliding, none.</i>
	<i>Refrigerator Volume</i>	
	<i>Freezer Volume</i>	
	<i>Total Volume</i>	
	<i>Height</i>	
	<i>Width</i>	
	<i>Depth</i>	
	<i>Daily Energy Consumption</i>	<i>Includes all plug load and heat energy extracted from the Case by the coolant line (for Cases with remote direct expansion and remote secondary cooling systems)</i>
	<i>Type of Illumination</i>	<i>T-8 fluorescent lamps with electronic ballasts, slim line T-12 fluorescent lamps with electronic ballasts, slim line T-12 fluorescent lamps with magnetic ballasts, other (specify LPW).</i>
	<i>Efficacy LPW (where Type of Illumination is required and is not T-8 fluorescent lamps with electronic ballasts) (for units manufactured on or after March 31, 2006 only)</i>	
	<i>Illumination Wattage</i>	
	<i>Evaporator Fan Motor Type</i>	<i>ECM or other high efficiency types</i>

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